

FORM PTO-1390 (REV 10-94)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		DOCKET #: 33900-73PUS	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371					
				U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/623208	
INTERNATIONAL APPLICATION NO. PCT/FR99/03322		INTERNATIONAL FILING DATE 30 December 1999		PRIORITY DATE CLAIMED 31 December 1998, 26 January 1999	
TITLE OF INVENTION Device and Process for the Heat Insulation of at Least One Underwater Pipe at Great Depth					
APPLICANT(S) FOR DO/EO/US Michel BAYLOT; Raymond HALLOT; Regis PIONETTI; Xavier ROCHER					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371</p> <p>3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).</p> <p>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</p> <p>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))</p> <p>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</p> <p>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</p> <p><input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input checked="" type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</p> <p>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>Items 11. to 16. Below concern other document(s) or information included:</p> <p>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.</p> <p><input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</p> <p>14. <input type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input checked="" type="checkbox"/> Other items or information (<i>specify</i>): PCT Publication Sheet, Int'l Search Report</p>					

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) 09/623208		INTERNATIONAL APPLICATION NO. PCT/FR99/03322		ATTORNEY'S DOCKET NUMBER 33900-73PUS	
17.[x] The following fees are submitted:					
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO \$840.00 International preliminary examination fee paid to USPTO (37 CFR 1.482)..... \$670.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$760.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$970.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)..... \$96.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$	840.00
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	28 - 20 =	8	x \$18.00	\$	144.00
Independent Claims	2 - 3 = 0		x \$78.00	\$	
Multiple dependent claim(s) (if applicable)			+ \$260.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	984.00
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$	984.00
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$	984.00
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by the appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				\$	40.00
TOTAL FEES ENCLOSED					\$1024.00
				Amount to be refunded:	\$
				charged:	\$
a. <input checked="" type="checkbox"/> Two check(s) in the amount(s) of \$ <u>984.00</u> and <u>\$40.00</u> to cover the above fees is/are enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. <u>03-2412</u> in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>03-2412</u> . A duplicate copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO: <u>Martin B. Pavane</u> Cohen, Pontani, Lieberman & Pavane 551 Fifth Avenue, Suite 1210 New York, New York 10176			<u>Martin B. Pavane</u> Registration Number: <u>28,337</u> Tel: (212) 687-2770		

422 Rec'd PCT/PTO 29 AUG 2000

By Express Mail # EL636862499US · August 29, 2000

Attorney Docket # 33900-73PUS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re National Phase PCT Application of

Michel BAYLOT et al.

International Appln. No.: PCT/FR99/03322

International Filing Date: 30 December 1999

For: Device and Process for the Heat Insulation of at
Least One Underwater Pipe at Great Depth

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents

Washington, D.C. 20231

BOX PCT

S I R:

Prior to examination of the above-identified application please amend the
application as follows:

In the Claims:

Please amend claims 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 17, 18, 19, 20, 21, 22, 24,
and 25 as follows:

3. Heat insulation device according to Claim 1 [or 2], characterized in that the
protective envelope (3) abutting on the material (4) which is solidified and rigid at least on

its periphery, is adapted to support the weight of the pipe (1) and the frictions when the latter is laid from the surface.

4. Heat insulation device according to [any one of claims 1 to 3] claim 1, characterized in that the protective envelope (3) is deformable in order to follow the variations in volume of the insulating coating that it contains under the effect of the hydrostatic pressure and upon variations in temperature.

5. Heat insulation device according to [any one of claims 1 to 4] claim 1, characterized in that the protective envelope (3) comprises at least one vent permeable to the gas that may diffuse through said underwater pipe (1) and generated by the effluents which circulate therein.

6. Device according to [any one of claims 2 to 5] claim 2, characterized in that the matrix (2) is constituted by a light, cellular or fibrous material and said virtually incompressible material (4) which impregnates it has a melting temperature (T_0) included between 20 and 80°C.

7. Device according to [any one of claims 1 to 6] claim 1, characterized in that said material (4) has a thermal conductivity less than 0.3 Watt/meter/degree Celsius in solid phase and an enthalpy of fusion greater than 50 kilojoule/kilogram.

8. Insulation device according to [any one of claims 2 to 7] claim 2, characterized in that said matrix (2) occupies only a part of the volume of the annular space defined by said protective envelope (3) and said pipe (1).

9. Device according to [any one of claims 1 to 8] claim 1, characterized in that it comprises distance pieces (9) regularly spaced apart along the pipe (1) on which they abut and supporting the protective envelope (3).

10. Device according to [any one of claims 1 to 9] claim 1, characterized in that the protective envelope (3) is made of thermoplastics material.

11. Device according to [any one of claims 1 to 10] claim 1, characterized in that said virtually incompressible material (4) is constituted, to at least 90%, of chemical compounds of the family of alkanes, preferably a paraffin comprising a hydrocarbon chain with at least 10 carbon atoms.

13. Heat insulation device according to [one of claims 1 to 12] claim 1, characterized in that the outer perimeter (24) of the transverse section of said protective envelope (3) is a closed curve of which the ratio of the square of the length over the surface that it defines is at least equal to 13.

17. Device according to [any one of claims 13 to 16] claim 16, characterized in that it comprises at least two pipes (I) disposed along the same plane and the transverse section of

said envelope (3) is of shape elongated in the same direction as this plane.

18. Device according to [any one of claims 13 to 16] claim 13, characterized in that the perimeter (24) of the transverse section of said envelope (3) comprises concave reversed curvatures (35).

19. Device according to [any one of claims 13 to 18] claim 13, characterized in that it comprises a wear plate (21) disposed on a part of said outer perimeter (24) of the envelope (3).

20. Device according to claim 19 [and according to any one of claims 14 to 17], characterized in that said wear plate (21) is disposed along one of the large sides of the transverse section of said envelope (3).

21. Device according to [any one of claims 13 to 20] claim 13, characterized in that the ratio of the square of the length of the outer perimeter (24) of the transverse section of said protective envelope (3) on the surface that said perimeter defines is at least equal to 16.

22. Device according to [any one of claims 13 to 21] claim 13, characterized in that the protective envelope (3) comprises a lower "U"-shaped part (3₁) in which are disposed said pipes (1) and a lid (34) assembled on this envelope (3).

24. Device according to [any one of claims 13 to 23] claim 13, characterized in that the protective envelope (3) comprises a lower “U”-shaped part (3₁) in which are disposed said pipes (1) and an upper opening closed by a layer (31) of supple material cast after installation of all the internal components.

25. Device according to [any one of claims 13 to 24] claim 13, characterized in that the envelope (3) comprises shims (27) supporting the insulating coating (2), the space included between the envelope (3) and said coating (2) being filled with a virtually incompressible fluid (4).

REMARKS

This preliminary amendment is presented merely to eliminate multiple dependency from the present claims. No new matter has been added. Early examination and favorable consideration of the above-identified application is earnestly solicited.

Any additional fees or charges required at this time in connection with the application may be charged to our Patent and Trademark Office Deposit Account No. 03-2412.

Respectfully submitted,
COHEN, PONTANI, LIEBERMAN & PAVANE

By: _____

Martin B. Pavane
Reg. No. 28,337
551 Fifth Avenue, Suite 1210
New York, N.Y. 10176
(212) 687-2770

29 August 2000

Device and process for the heat insulation of at least one underwater pipe at great depth

The present invention has for its object devices and processes for the heat insulation of at least one underwater pipe at great depth.

5 The technical sector of the invention is the domain of the manufacture and assembly of an insulation system outside and around the pipes in which hot effluents, of which it is desired to limit heat losses, circulate.

10 This invention is applied more particularly to the developments of deep-sea oil fields, i.e. oil rigs installed on the open sea, in which the surface equipment is generally located on floating structures, the well heads being on the sea bed. The pipes concerned by the present invention are either links between well heads, or the part resting on the bed of the bed/surface links.

Deep-sea developments are at the present time effected at water depths reaching 1500 meters. Future developments are envisaged at depths of up to 3000 meters and more.

15 The principal application of the invention is the heat insulation of pipes or lines immersed under water and more particularly at great depth, beyond 300 meters, and conveying hot oil products of which too great a cooling would be problematic both during normal production and in the case of production being stopped.

20 In effect, in this type of application, numerous problems are raised if the temperature of the oil products decreases by a significant considerable value with respect to their production temperature which is generally beyond 60 to 80°C, while the temperature of the surrounding water, especially at great depth, may be less than 10°C. If the oil products cool for example below 30° to 60°C, for an initial temperature of 70 to 80°C, the following is generally observed:

- 25 - a considerable increase in the viscosity which then reduces the flowrate of the pipe,
- a precipitation of dissolved paraffin which then increases the viscosity of the product and of which the deposit may reduce the useful internal diameter of the pipe,
- the flocculation of the alphasenes inducing the same problems,
- the sudden, compact and massive formation of gas hydrates which precipitate at high pressure and low temperature, thus suddenly obstructing the pipe.

30 Paraffins and alphasenes remain attached to the wall and then require cleaning by scraping the inside of the pipe; on the other hand, the hydrates are still more difficult, and

even impossible to remove.

The function of the heat insulation of such pipes is therefore to delay cooling of the oil effluents conveyed, not only during established production for their temperature to be for example at least 40°C on arriving at the surface, for a production temperature at the entrance
 5 of the pipe of 70°C to 80°C, but also in the case of reduction or even stoppage of production in order to avoid the temperature of the effluents descending for example below 30°C in order to limit the problems mentioned above or at least allow them to be rendered reversible.

Moreover, when such pipes are to be laid at depths greater than 300 meters, the ambient pressure of at least 30 bars prevents the use of high-performance heat insulators
 10 which are encountered on land or at shallow immersion, as they all use gases of which the heat conductivity is in effect very low and whose convection is blocked by a solid, porous, cellular or fibrous material: however, the compressivity of the gases does not allow these conventional heat insulators to withstand high outer pressures.

Japanese Patent Application No. JP2176299 published on 25.10.91 might also be
 15 cited, which describes a device for insulating metallic or synthetic resin tubes for supplying hot water in buildings and of which it is desired to conserve the temperature at more than 50°C after one hour of stoppage of supply of hot water, in an ambient temperature of 13°C for example: to that end, it describes a structure comprising a tube for the circulation of hot water, which is preferably deformable to facilitate laying thereof, with a layer of porous material
 20 imbibed with paraffin to about 200% and covering it, and another layer of refractory material covering the periphery of the assembly; the use of paraffin makes it possible to have an advantageous coefficient of heat insulation although less than the heat insulators mentioned above and comprising gas, but the capacity of heat accumulation of this Japanese device is reinforced by the presence of the outer refractory layer making it possible to reduce heat loss
 25 with the advantage of being able to cut the whole of this structure at any spot in order to facilitate assembly thereof and without loss of the heat accumulation power. However, such a solution cannot be used in water, especially at great depth where it is necessary to be able to withstand a considerable outer hydrostatic pressure, while ensuring sufficient containment in order to avoid any risk of pollution and/or loss of thermal efficiency. Moreover, it does not
 30 contribute the specific characteristics described and claimed in the present invention.

Moreover, other specific types of heat insulation compatible with deep immersions

have rathermore been developed, which may be grouped in three families, namely:

- the outer coatings made of solid plastic such as polyurethane, polyethylene, polypropylene... but whose heat conductivity is fairly average since of the order of 0.2 to 0.3 Watt/meter/degree Celsius, which may be sufficient in continuous production but insufficient to preserve a minimum temperature for a given time in the event of stoppage of production,

- the coatings made of syntactic materials constituted by hollow balls containing a gas and resistant to the outside pressure and embedded in various binding agents such as concrete, epoxy, elastomer, polypropylene, etc...: the ones with highest performance are the syntactic materials based on epoxy binding agent and on hollow glass microspheres of fairly low conductivity and interesting since of the order of 0.10 to 0.15 watt/meter/degree Celsius, but the cost of these coatings is very high,

- the "pipe in pipes" in which a first inner tube conveying the effluents is disposed concentrically in a second tube resistant to the outside hydrostatic pressure; the annular space included between the two tubes may either be filled with heat insulator with very low heat conductivity (0.02 Watt/meter/degree Celsius) and which, in order not to be crushed, must be left at atmospheric pressure, or a vacuum may be created therein: such a solution necessitates partitions disposed longitudinally and perfectly tight, at regular intervals, for questions of safety, and complicates the construction and positioning of such assemblies which are, moreover, very expensive.

Another technique consists in prefabricating shells of syntactic foam and in assembling them around the pipe or in making a continuous coating of syntactic foam around said pipe. We would recall on this subject that the syntactic foam is constituted by hollow microspheres containing a gas and bonded by a resin generally of the epoxy type.

These deep-sea insulation technologies use very high-performance products which are extremely expensive and difficult to employ on a large scale.

In the case of installing single pipes or so-called bundles of pipes, it is generally preferred to manufacture said pipes on land in unitary lengths of 500 to 1000 m which are then pulled from the open sea with the aid of a tugboat. In the case of pipes of several kilometers, the first length is pulled, which is joined to the following, the tugboat maintaining the whole in traction during the joining phase, which may last several hours. When all the pipe or

bundles of pipes has been put in the water, the whole is towed, generally rubbing on the seabed, towards the site, where it is then placed in position.

The insulation of the pipe or pipes or of the bundle is then protected by an outer envelope which has a double function: - on the one hand that of avoiding damage which might occur during towing, which may in certain cases take place over distances of several hundreds of kilometers, which requires using fairly resistant materials such as steel, thermoplastic or thermosetting compound or a composite material; - on the other hand, that of creating a containment around the insulation system.

Such containment is necessary in the case of outer insulating coatings constituted by shells of syntactic foam assembled around the pipes, as the interstices existing between the various shells, as well as the space between the shells and the outer envelope, are filled with a virtually incompressible product, which is generally fresh water or passivated sea water or any other product compatible with the internal components.

In effect, with sea-beds of 2000 m, the hydrostatic pressure is of the order of 200 bars, or 20 Mega Pascals, which implies that all the pipes and the insulating system thereof must be capable of withstanding not only these pressures without degradation during pressurizations and depressurizations of the pipe in which the hot fluid circulates, but also the temperature cycles which will generate variations in volume of the different components as well as of the interstitial fluids, and therefore positive or negative pressures which may lead, if the outer envelope is tight, to partial or total destruction thereof either by exceeding the stresses admissible, or by implosion of this outer envelope (negative variations of internal pressure).

If said outer envelope is not tight, the assembly will then be at equal pressure with respect to the outer pressure, but this will then result in exchanges of fluids between the interior of the bundle and the outer medium. In the case of a filling of the interstices of the bundle with fresh water, passivated sea water or any other product compatible with the internal components as indicated hereinabove, as it is in that case sought to avoid fluid exchanges with the outer medium, one is led to arrange bags constituted by a supple membrane of elastomer type making it possible to contain the variations in volume by maintaining the variations in pressure at a reasonable level but these bags then complicate assembly of the insulating device and do not enable the stresses to be distributed in uniform manner.

The problem raised is therefore that of being able to produce an insulation of at least one underwater pipe intended to be laid on the sea-bed in particular at great depth, of which the insulating coating can withstand not only the hydrostatic pressure but also all the efforts associated with its own weight, and induced upon laying during which the pipe undergoes frictions and is exposed to risks of punching ; said insulating coating must make it possible to maintain for example a hot effluent such as an oil product produced for example at 60°C at the level of the sea-bed, at a temperature above for example 40°C when it arrives on the surface after a distance of several kilometers in the water, and, moreover, to maintain a temperature at more than 30°C for example even after several hours of stoppage of production, and this with manufacturing costs which are less than those of present syntactic materials, while offering various possibilities of implementation, and this without risk of pollution for the environment.

One solution to the problem raised is a device for insulating at least one underwater pipe (which may in effect be alone or assembled with other pipes, then constituting what is called "bundles"), intended to be laid on the sea-bed at great depth, comprising an insulating coating surrounding the latter and a protective envelope; according to the invention, said insulating coating comprises a virtually incompressible, liquid-solid phase change material with a melting temperature T_0 higher than that T_2 of the medium surrounding the pipe in operation and less than that T_1 of the effluents circulating in the pipe, which protective envelope is resistant (such as to abrasion, to friction, to corrosion and to mechanical impacts) and deformable (in particular to follow the variations in volume of the phase change material under the effect of the hydrostatic pressure and/or upon variations in temperatures), ensures a containment around said insulating coating, in particular a containment around and against said insulating coating.

Said insulating coating preferably comprises an absorbent matrix surrounding the pipe, preferably nearest the outer surface of said pipe, said matrix being impregnated with said virtually incompressible material.

Said insulating coating may surround the pipe directly or indirectly. In the latter case said insulating coating may surround a pipe itself already insulated, in particular by syntactic foam.

The protective envelope, bearing on the material, solidified and rigid at least on its

periphery, is adapted to withstand the weight of the pipe and the frictions when the latter is laid from the surface.

More particularly, the protective envelope is deformable in order to follow the variations in volume of the insulating coating under the effect of the hydrostatic pressure and upon variations in temperature.

This envelope may present at least one gas-permeable vent so as to avoid possible accumulations of gas such as the hydrogen which might diffuse through the wall of the inner pipe, which hydrogen may be generated by the effluents circulating therein.

The object of the present invention is also achieved by a process of insulation using an insulating coating surrounding at least one underwater pipe and a protective envelope, such that:

- said pipe is surrounded, preferably directly, with an insulating coating comprising a virtually incompressible, liquid-solid phase change material with a given melting temperature T_0 , said incompressible material preferably being impregnated in an absorbant matrix, and the whole is contained in the protective envelope which must be resistant and deformable,

- there are made to circulate in said pipe hot effluents at a temperature T_1 higher than the melting temperature T_0 of the material while the ambient outside temperature T_2 is less than T_0 , the phase change material then being liquefied, preferably in a part of the impregnation matrix from the pipe up to a limit of heat exchange equilibrium between the pipe and the envelope, beyond this limit the material being solid,

- when the circulation of the effluents in the pipe is stopped, the temperature of these effluents is maintained above a given temperature T_3 for a predetermined duration thanks to the heat transfer brought by the latent heat of solidification of the material of which the liquid part solidifies progressively on cooling.

The result is a novel device and process for insulating at least one underwater pipe intended to be laid on the sea-bed in particular at great depth, avoiding the drawbacks mentioned hereinabove in the present known devices and responding to the problem raised. In effect, the outer protective envelope does not need to be resistant to the hydrostatic pressure since it bears on a virtually incompressible material.

Such materials are chosen also to be liquid/solid phase change materials with a melting temperature T_0 higher than that T_2 of the medium surrounding the pipe in operation in order

that its outer part is always solid, and therefore on the one hand resistant enough to absorb the efforts transmitted by the outer protective envelope, on the other hand, contributing a better thermal inertia. Said melting temperature T_0 must also be chosen to be less than that of the effluent circulating in the pipe, so that that part of this material surrounding the pipe is

5 liquefied thanks to the calorific addition of the effluents in normal production. On the other hand, in the case of production slowing down or even in the case of stoppage thereof, said phase change material restores its calories to the effluents contained in the pipe, thanks for example to a enthalpy of fusion greater than 50 kilojoule/kilogram, which delays cooling of said effluents by as much and allows the desired objects to be achieved.

10 Moreover, the outer solid part of said phase change material limits the risks of pollution of this material in the surrounding medium since, in the event of the outer protective envelope tearing, the solidity of this part of the material maintains its integrity.

Said virtually incompressible material is chosen for its low heat conductivity, particularly less than 0.3 watt/meter/degree Celsius.

15 Said incompressible material is chosen in particular from the materials constituted by at least 90% of chemical compounds chosen from alkanes, in particular comprising a hydrocarbon chain with at least 10 carbon atoms, or salts, hydrated or not, glycols, bitumens, tars, waxes, and other fatty bodies solid at ambient temperature, such as tallow, margarine or fatty alcohols and fatty acids.

20 The incompressible material is preferably constituted by paraffin comprising a hydrocarbon chain with at least 14 carbon atoms.

The phase change materials described hereinabove generally present a considerable variation in volume during their change of state, which may attain 20% in the case of paraffins. The outer protective envelope must be able to adapt itself without damage to these

25 variations in volume.

Another object of the present invention is therefore also to produce an envelope for protecting the insulation system making it possible, on the one hand, to ensure the integrity of a bundle of pipes and of its insulation system when it is towed and installed in situ and, on the other hand, to overcome the stresses generated by the differential expansion of the various

30 components during the variations in temperature associated with the stresses due to the pressure of the sea bed.

This object is attained by a device for the heat insulation of at least one underwater pipe comprising an insulating coating surrounding the latter and a protective envelope such as according to the present invention, the outer perimeter of the transverse section of said protective envelope is a closed curve of which the ratio of the square of the length over the surface that it defines is at least equal to 13; the protective envelope, which surrounds and ensures containment of the insulating coating, follows the outer shape thereof, and its transverse section which is therefore not circular - as has been usual to do up to the present time - is an oval, a polygon such as a rectangle, or a combination of the two.

In the case of the device comprising at least two pipes disposed in the same plane, the transverse section of said envelope is of shape elongated in the same direction as this plane.

Upon variations in internal volume, the envelope will tend to be deformed towards a circular shape, which mathematically constitutes the shape presenting, with constant perimeter, the largest section.

In the case of a tight envelope of circular profile, an increase in volume generates stresses in the wall, which are associated with the increase in pressure resulting from this increase in volume.

On the contrary, in the case of a rectangular profile, an increase in volume will principally generate flexions of the planar walls, the migration of the interstitial fluids grouping together in these zones of deformation. The efforts generated in the wall will be principally bending efforts in the thickness of the wall, the greatest bendings being produced on the large sides, insofar as the envelope presents a constant thickness over its periphery and over the whole of its length.

By way of example, a circle of diameter 1 m presents an approximate section of 0.785 m² for an approximate perimeter of 3.1416 m: a square of the same perimeter presenting an approximate section of 0.617 m², this shape offers a capacity of expansion of 21.5% when, with constant perimeter, the square shape passes to a circular shape; this square shape corresponds to a value of the ratio of the square of the length of its outer perimeter of the closed curve of the transverse section of the protective envelope, with respect to the surface that said perimeter defines, equal to 16.

Similarly, a flattened rectangular shape of which the above ratio is then greater than 16 will present, with constant perimeter, a greater theoretical capacity of expansion; in this way, a

rectangle with a large side measuring 1.2 m and a small side of 0.3708 m which has the same perimeter of 3.1416 m, but a section of only 0.44496 m², presents a theoretical capacity of expansion of 43.3%.

It thus appears that, the more the shape of the transverse section of the insulating coating is flattened, the better the capacity of its envelope is to absorb the expansions due to the expansion of the components under the effect of the temperature.

However, it must not be forgotten that not all of the theoretical capacity of expansion is available, as the deformation by bending of the wall will tend towards the shape of a very imperfect circle. In this way, the effective capacity of expansion is only a portion of said theoretical capacity of expansion and may then correspond to 30% or 50% depending on the quality of the material constituting the envelope, which envelope may be made of steel, thermoplastics or thermosetting compound or of composite material.

Thus, for considerable variations in volumes, profiles will advantageously be used, of which the perimeter of the transverse section of said outer envelope comprises concave reversed curvatures whose concavity is turned towards the outside of said envelope.

In the case of a profile of oval shape, a variation in internal pressure will involve a combination of bending stresses and of pure tensile stresses, as the variable curvature of the oval then behaves as an architectural vault with, however, the difference that, in the case of our envelope, the stresses are tensile stresses and not compression stresses. An oval or approximately oval shape will be thus be able to be envisaged for small capacities of expansion and it will in that case be appropriate to consider ovals with a ratio of length of the large axis ρ_{\max} over that of the small axis ρ_{\min} as high as possible, for example at least 2/1 or 3/1.

The shape of the envelope will then be selected as a function of the overall expansion sought of the volume of the insulating coating, under the effect of variations in temperature. In this way, for a system of insulation using principally materials subject to expansion, a rectangular shape, a polygonal shape or an oval shape allow an expansion by bending of the wall while inducing a minimum of tensile stresses in the outer envelope.

For a fluid presenting a great expansion under the effect of variations in temperature, such as gas oil, products of the family of alkanes (paraffins), or phase change materials, the rectangle will advantageously be flattened in order to create the necessary reserve of

expansion. This expansion reserve may further be increased by creating the reversed curvatures mentioned hereinabove.

Other advantages of the present invention may be cited, but those mentioned above already show sufficient to prove the novelty and interest thereof. The following description of the Figures concerns embodiments of the invention but has no limiting character: other
 5 embodiments are possible within the scope and extent of this invention, in particular by choosing a liquid/solid phase change material specific to the applications desired in terms of depth of immersion, temperature of the ambient medium, temperature of the effluents....

Figure 1 is a view in section of an insulation device according to the present invention
 10 shown here with three pipes assembled together in a bundle, but which may be adapted to a single pipe or a larger number of joined pipes.

Figures 2A and 2B show details of the phases of the process of assembly and manufacture of the insulation device according to the invention as shown in Figure 3E.

Figures 3A to 3E and 4A to 4C show different phases of an example of process of
 15 insulation according to the present invention.

Figures 5A and 5B show sections of a device according to the invention specific to the connection between two sections of pipe.

Figure 6 is a view in section of a bundle of two pipes whose insulating coating and protective envelope are of circular shape and constitute the known prior art.

Figure 7 is a view in section of an envelope of a bundle of conduits according to the
 20 invention, of square cross-section.

Figure 8 is a view in section of an envelope of polygonal cross-section.

Figure 9 is a view in section of an envelope of flattened rectangular cross-section at ambient temperature and in position of maximum expansion due to the temperature.

Figure 10 is a view in section of an envelope of oval cross-section of ratio 3/1.

Figure 11 is a view in section of an envelope of oval cross-section of ratio 2/1.

Figure 12 is a view in section of an envelope of flattened rectangular cross-section with rounded ends.

Figure 13 is a view in section of an envelope of curved cross-section presenting points
 30 of inflexion, therefore reversed curvatures.

Figure 14 is a view in section of a bundle constituted by a multiplicity of pipes, power

and control cables, disposed flat according to the present invention, insulated by an insulating coating and protected by a protective envelope of flattened, substantially rectangular cross-section, and comprising a lower wear plate.

Figure 15 is a view in section of a bundle according to the invention of flattened, substantially rectangular cross-section, manufactured from metal plates and presenting a welded lid.

Figure 16 is a view in section of a variant of the preceding bundle in which the lid may be either welded or assembled mechanically.

Figure 17 is a view in section of a variant of the preceding bundle in which the heat is replaced by a supple and resistant product cast in situ.

Example 1: Insulating coating based on paraffin.

As indicated hereinabove, the device for insulating at least one underwater pipe 1 intended to be laid on the sea-bed 8 at great depth, comprises in known manner an insulating coating surrounding the latter and a protective envelope 3. According to the present invention as shown in the accompanying Figures, said insulating coating is composed of a virtually incompressible liquid-solid phase change material with a melting temperature T_0 higher than that T_2 of the medium surrounding the pipe in operation and less than that T_1 of the effluents 6 circulating in the pipe 1; which material 4 has a fairly low heat conductivity preferably less than 0.3 watt/meter/degree Celsius in solid phase and a enthalpy of fusion preferably greater than 50 kilojoules/kilogram: it is for example constituted by at least 90% of chemical compounds of the family of alkanes which are saturated hydrocarbons of general formula $C_n H_{2n+2}$ such as for example paraffins or waxes; said chemical compounds also being able to be salts, hydrated or not, glycols, bitumens, tars, fatty alcohols; the melting temperature of said material must therefore be included between the temperature T_1 of the hot effluents 6 circulating in the pipe 1 and T_2 of the medium 5 surrounding the pipe in operation, or in fact in general a melting temperature included between 20 and 80°C. Tetracosane of formula $C_{24} H_{50}$ presenting a temperature T_0 of 50.9°C is, for example, used as paraffin.

The insulating coating according to the invention is constituted by an absorbent matrix 2 surrounding the pipe 1 nearest its outer surface and impregnated with said incompressible material 4; said protective envelope 3 is resistant and deformable and ensures a containment against and around said insulating coating: this protective envelope 3, bearing on the material

4, solidified and rigid at least on the periphery, is adapted to support the weight of the pipe 1 and the frictions when the latter is laid from the surface.

Said protective envelope 3 is deformable to compensate at least the variations in volume of the insulating coating that it contains, on the one hand under the effect of the hydrostatic pressure and, on the other hand, upon the variations in volume of the material 4 during its phase change, in order to preserve its integrity and therefore its capacity of containment; this protective envelope 3 may to that end be made of thermoplastics material such as polyethylene or of thermosetting material or even metal, of non-cylindrical cross-section. Under the action of the outside hydrostatic pressure, this protective envelope 3, forming an outer tube, is deformed and abuts on the solidified part of the material 4 which is of virtually incompressible nature: in this way, the deformation of this protective envelope 3 remains small and the resulting stresses will also be small; consequently, the thickness of said envelope may also be small.

Said matrix 2 may be constituted by a light cellular or fibrous material such as open-cell foam, particularly polyurethane foam, glass or rock fiber, woven fabrics, felt, paper, etc...: in fact, the nature of the material constituting said matrix must be sufficiently absorbent to be compatible with the impregnation by said phase change material 4 in order to oppose the natural convection of the liquefied part 4_1 of said material; this matrix may possibly be heterogeneous in order to be compatible with the temperature gradient of the impregnation and it may occupy only a part of the volume of the annular space defined by said protective envelope 3 and said pipe 1 insofar as the outer part 4_2 of said phase change material always remains solid and is therefore not subject to heat convection movements: in that case, the limit 19 between the two liquid (4_1) and solid (4_2) parts is always included in the matrix 2.

An absorbent matrix constituted by tufted floor carpet may for example be used..

According to the example of a process for producing a device according to the invention as shown in Figures 3A to 4C:

- an obturator 7_2 is fixed, such as by continuous welding 16_1 , to one end of the outer pipe wall 1 to be insulated (Figure 3);

- there are mounted on this part of pipe 1 elements of the absorbent matrix 2 which surrounds the latter completely and uniformly and there is fitted around these matrix elements 2 the outer protective envelope 3 which is connected, such as by continuous welding, at its

end to the obturator 7₂ (Figures 3B and 3C); according to a preferred embodiment, there are also interposed between elements of absorbent matrix 2, distance pieces 9 regularly spaced along the pipe 1 on which they abut and are adapted to centre and support the protective envelope 3;

5 - a second obturator 7₁ is positioned at the other end of the protective envelope 3, which is fixed on this envelope and on the pipe 1 such as by continuous welding 16₂ (Figure 3D);

10 - in the event of distance pieces 9 having been interposed between the matrix elements 2, when all the elements of the protective envelope 3 have thus been placed in position and fixed in order thus to constitute the containment envelope, straps 17 for maintaining said distance pieces 9 plumb are placed in position (Figure 4B);

15 - the annular space included between the pipe 1 and the envelope 3 is completely filled, for example via one end thanks to orifices 14 made in one of the obturators 7, with said phase change material 4 liquefied and overheated above its melting temperature T₀, and this until the matrix elements 2 are completely impregnated thereby. To that end, said pipe may be inclined in order to fill said phase change material 4 by the lower part of the annular space as shown in Figure 4A, which makes it possible to drive the air through vents 15 disposed in the obturator 7 opposite the one allowing filling (a vacuum may also be made before such filling);

20 - in the case of distance pieces 9 and holding straps 17 having been previously disposed, the annular space is filled with said liquefied material 4 under pressure in order to deform the outer envelope 3 between said straps 17; the desired elastic line corresponding to the increase in volume, or overvolume, generated by the heat expansion of the material 4, liquid at filling temperature, as shown in Figure 4B, and with respect to its volume in the solid state;

25 - the whole is cooled, and after cooling and solidification of the material 4, the latter resumes substantially its initial volume: if filling was effected under pressure as indicated previously, the outer envelope will then be substantially straight as indicated in Figure 4C, which will enable said straps 17 to be removed.

30 The bodies of the obturators 7 are closed, and those of the distance pieces 9 are preferable perforated to allow filling of the phase change material: these obturators and distance pieces are made of non-metallic material which is preferably hardly heat-conducting.

As indicated in Figures 2A and 2B, said obturators may also comprise an inner ring 10 of the same material as that of the pipe 1 and an outer ring 11 of the same material as that of the outer tube 3; these two possible rings are fixed on the body of the obturator in rigid and tight manner; the one fixed on the pipe 1 may comprise a flange 10 for assisting handling.

5 The distance pieces 9 are necessary in the case of the mechanical strength of the rigid part 2₂ of the phase change material not being sufficient to support the or each pipe 1; moreover, such distance pieces 9 ensure the centering of the or each bundle of pipes in the outer envelope tube 3.

10 In the case of a pipe assembled in situ by welding or screwing previously insulated elementary sections, the areas of join then lack insulation and must be treated in situ: this insulation may for example be completed in this area by disposing a plurality of prefabricated impregnation blocks 12 fitting on one another around the join between sections, the whole being immobilized by overmoulding by a thermoplastics or thermosetting resin 13 as shown in Figures 5A and 5B.

15 Example 2: flat bundle of at least two pipes side by side.

Figure 6 is a view in section of a device for heat insulation of two underwater pipes 1 comprising an insulating coating 2 surrounding them and a protective envelope 3 containing the whole. Said insulating coating 2 is composite as in Example 1 and the perimeter 24 of the transverse section of the whole is a circle; a virtually incompressible fluid ensures integral
20 filling of the envelope 3 by filling all the interstices which might exist between said half-shells and said envelope 3; the latter, in order not to undergo considerable stresses essentially due to the variations in temperature, as explained hereinabove, in that case comprises a continuous channel 23 over the whole of its length and against its inner wall to facilitate the movements of the virtually incompressible fluid and maintain the whole under equal pressure; the
25 envelope 3 also presents either at its ends or at multiple points distributed over its length, orifices placing said fluid in contact with the outside either directly or indirectly via a supple membrane in order to avoid the mixture between the sea water and said virtually incompressible fluid.

30 Figure 7 is a transverse section of the device for heat insulation of the bundle according to the invention in which the outer perimeter 24 of the transverse section is of square shape and protects an insulation of an insulating coating 2 composed of paraffin as

described in Example 1, preferably impregnated in an absorbent matrix.

Figure 8 is a section of a variant of the device of Figure 7 in which the envelope 3 is octagonal.

Figure 9 is a section of a variant of the device of Figure 7 in which the envelope 3 is rectangular and of flattened shape. Under the effect of the variations in temperature, the expansion of the insulating coating 2 is contained in the deformation of the envelope 3 which takes the shape of the profile of curve 37.

Figure 10 is a section of a variant of Figure 7 in which the envelope 3 is of oval shape, of which the ratio of length of the large axis over that of the small axis is equal to 3/1.

Figure 11 is a section of a variant of Figure 7 in which the envelope 3 is an oval of which the ratio of the large axis over the small axis is equal to 2/1.

Figure 12 is a section of a variant of Figure 7 in which the envelope 3 is of flattened rectangular shape of which the small sides 28 are convex or rounded.

Figure 14 (sic) is a section of a variant of Figure 7 in which the perimeter 24 of the transverse section of the envelope 3 comprises points of inflexion, therefore concave reversed curvatures 5 (sic) increasing the capacity of expansion.

Figure 14 is a section of a heat insulation device according to the invention of which the envelope 3 contains two pipes 1₁ for producing oil effluents, a central pipe 1₂ for injecting water and two pipes for heating the whole, pipe 1₃ serving for example to send a hot fluid from the surface support, pipe 1₄ serving for the return; a link between pipes 1₃ and 1₄ existing at the second immersed end of the bundle of pipes. These pipes 1 are surrounded by an insulating coating filled with a virtually incompressible fluid such as paraffin, as described in Example 1. The bundle of pipes is equipped on its sides with chutes 29 adapted to receive umbilicals 20, said chutes being shown single to the left, and double to the right of Figure 14.

The heat insulating device according to the invention comprises in its lower part a wear plate 11 disposed on a part of the outer perimeter 24 of the transverse section of the protective envelope 3, and preferably at least along one of the large sides of said transverse section, in that case making it possible to avoid any damage of the containment envelope 3 during the operation of towing and installation in situ: the whole resting on the sea bed 22, only the wear plate 21 rubs against the latter.

Said wear plate 21 may be made of thermoplastics material of density 1 therefore not

modifying the floatability of the whole during towing nor even during the life of the bundle of pipes in situ.

Figure 15 is a section of a bundle of which the protective envelope 3 comprises a lower part 3₁ in the form of an upwardly open "U" in operational position, in which are disposed said pipes 1, the insulating coating 2 and the incompressible fluid 4, said lower part 3₁ being closed by a lid 34 assembled on the latter in order to constitute the whole of the protective envelope 3; the latter is shown in substantially rectangular shape and made for example from a shaped metal sheet equipped with a lid 34 assembled by welding at 25₁, 25₂ on said envelope. The bundle contains pipes 1 and electrical heating lines 26, the whole being contained in a coating 2 supported by shims 27, disposed in the lower part of the envelope 3; said coating 2 being constituted either by an absorbent matrix impregnated with paraffin, or by syntactic foam or any other pressure-resistant insulating product; the space included between the envelope 3 and the insulating coating 2 being filled with virtually incompressible fluid 4, such as paraffin, ensuring integral filling of the inner volume of the envelope 3 which in this embodiment therefore does not follow the shape of the insulating coating 2.

Figure 16 is a variant of Figure 15 in which the envelope 3 and the lid 34 present a lip-shaped overlapping 28 located outside the principal section of the bundle, which allows an assembly to be made,

- either as shown in the left-hand side of the Figure, by bolting or riveting through regularly spaced apart holes 29, associated with the positioning of an elastomer joint 30₁ or by simple adhesion between the sheets,

- or by continuous seam welding in zone 30₂ as shown in the right-hand side of the Figure; said seam welding being known to the person skilled in the art of boiler construction, will not be described here.

In this way, in the case of mechanical assembly, of adhesion or of the combination of the two, the envelope 3 may be made of any materials such as metals, thermoplastics, thermosetting materials or composite materials.

Figure 17 is a variant of Figure 15 in which the lid is replaced by a layer 31 of supple material such as thermoplastics, thermosetting or polymerizable material, for example elastomer, which material closes the upper opening of the U-shaped lower part 3₁ of the envelope 3 and is cast in situ after complete installation of all the components of the bundle,

an insulating coating 2 comprising a virtually incompressible fluid 4, said insulating coating 2 being surrounded by incompressible filling fluid 4 of which the level will then be adjusted so as to allow sufficient place to ensure a sufficient thickness for the layer 31, for example 1 cm, thus allowing a sufficient adherence on the wall of the envelope 3. The contact surface is

5 shown in the right-hand part of the Figure in the form of a right angle 32, in the left-hand part an S-shape 33 of the sheet 3 increases the contact surfaces as well as the zones subjected to shear, which shear is generally preferable to tear in adhesions.

11
 12
 13
 14
 15
 16
 17
 18
 19
 20
 21
 22
 23
 24
 25
 26
 27
 28
 29
 30
 31
 32
 33
 34
 35
 36
 37
 38
 39
 40
 41
 42
 43
 44
 45
 46
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56
 57
 58
 59
 60
 61
 62
 63
 64
 65
 66
 67
 68
 69
 70
 71
 72
 73
 74
 75
 76
 77
 78
 79
 80
 81
 82
 83
 84
 85
 86
 87
 88
 89
 90
 91
 92
 93
 94
 95
 96
 97
 98
 99
 100
 101
 102
 103
 104
 105
 106
 107
 108
 109
 110
 111
 112
 113
 114
 115
 116
 117
 118
 119
 120
 121
 122
 123
 124
 125
 126
 127
 128
 129
 130
 131
 132
 133
 134
 135
 136
 137
 138
 139
 140
 141
 142
 143
 144
 145
 146
 147
 148
 149
 150
 151
 152
 153
 154
 155
 156
 157
 158
 159
 160
 161
 162
 163
 164
 165
 166
 167
 168
 169
 170
 171
 172
 173
 174
 175
 176
 177
 178
 179
 180
 181
 182
 183
 184
 185
 186
 187
 188
 189
 190
 191
 192
 193
 194
 195
 196
 197
 198
 199
 200
 201
 202
 203
 204
 205
 206
 207
 208
 209
 210
 211
 212
 213
 214
 215
 216
 217
 218
 219
 220
 221
 222
 223
 224
 225
 226
 227
 228
 229
 230
 231
 232
 233
 234
 235
 236
 237
 238
 239
 240
 241
 242
 243
 244
 245
 246
 247
 248
 249
 250
 251
 252
 253
 254
 255
 256
 257
 258
 259
 260
 261
 262
 263
 264
 265
 266
 267
 268
 269
 270
 271
 272
 273
 274
 275
 276
 277
 278
 279
 280
 281
 282
 283
 284
 285
 286
 287
 288
 289
 290
 291
 292
 293
 294
 295
 296
 297
 298
 299
 300
 301
 302
 303
 304
 305
 306
 307
 308
 309
 310
 311
 312
 313
 314
 315
 316
 317
 318
 319
 320
 321
 322
 323
 324
 325
 326
 327
 328
 329
 330
 331
 332
 333
 334
 335
 336
 337
 338
 339
 340
 341
 342
 343
 344
 345
 346
 347
 348
 349
 350
 351
 352
 353
 354
 355
 356
 357
 358
 359
 360
 361
 362
 363
 364
 365
 366
 367
 368
 369
 370
 371
 372
 373
 374
 375
 376
 377
 378
 379
 380
 381
 382
 383
 384
 385
 386
 387
 388
 389
 390
 391
 392
 393
 394
 395
 396
 397
 398
 399
 400
 401
 402
 403
 404
 405
 406
 407
 408
 409
 410
 411
 412
 413
 414
 415
 416
 417
 418
 419
 420
 421
 422
 423
 424
 425
 426
 427
 428
 429
 430
 431
 432
 433
 434
 435
 436
 437
 438
 439
 440
 441
 442
 443
 444
 445
 446
 447
 448
 449
 450
 451
 452
 453
 454
 455
 456
 457
 458
 459
 460
 461
 462
 463
 464
 465
 466
 467
 468
 469
 470
 471
 472
 473
 474
 475
 476
 477
 478
 479
 480
 481
 482
 483
 484
 485
 486
 487
 488
 489
 490
 491
 492
 493
 494
 495
 496
 497
 498
 499
 500
 501
 502
 503
 504
 505
 506
 507
 508
 509
 510
 511
 512
 513
 514
 515
 516
 517
 518
 519
 520
 521
 522
 523
 524
 525
 526
 527
 528
 529
 530
 531
 532
 533
 534
 535
 536
 537
 538
 539
 540
 541
 542
 543
 544
 545
 546
 547
 548
 549
 550
 551
 552
 553
 554
 555
 556
 557
 558
 559
 560
 561
 562
 563
 564
 565
 566
 567
 568
 569
 570
 571
 572
 573
 574
 575
 576
 577
 578
 579
 580
 581
 582
 583
 584
 585
 586
 587
 588
 589
 590
 591
 592
 593
 594
 595
 596
 597
 598
 599
 600
 601
 602
 603
 604
 605
 606
 607
 608
 609
 610
 611
 612
 613
 614
 615
 616
 617
 618
 619
 620
 621
 622
 623
 624
 625
 626
 627
 628
 629
 630
 631
 632
 633
 634
 635
 636
 637
 638
 639
 640
 641
 642
 643
 644
 645
 646
 647
 648
 649
 650
 651
 652
 653
 654
 655
 656
 657
 658
 659
 660
 661
 662
 663
 664
 665
 666
 667
 668
 669
 670
 671
 672
 673
 674
 675
 676
 677
 678
 679
 680
 681
 682
 683
 684
 685
 686
 687
 688
 689
 690
 691
 692
 693
 694
 695
 696
 697
 698
 699
 700
 701
 702
 703
 704
 705
 706
 707
 708
 709
 710
 711
 712
 713
 714
 715
 716
 717
 718
 719
 720
 721
 722
 723
 724
 725
 726
 727
 728
 729
 730
 731
 732
 733
 734
 735
 736
 737
 738
 739
 740
 741
 742
 743
 744
 745
 746
 747
 748
 749
 750
 751
 752
 753
 754
 755
 756
 757
 758
 759
 760
 761
 762
 763
 764
 765
 766
 767
 768
 769
 770
 771
 772
 773
 774
 775
 776
 777
 778
 779
 780
 781
 782
 783
 784
 785
 786
 787
 788
 789
 790
 791
 792
 793
 794
 795
 796
 797
 798
 799
 800
 801
 802
 803
 804
 805
 806
 807
 808
 809
 810
 811
 812
 813
 814
 815
 816
 817
 818
 819
 820
 821
 822
 823
 824
 825
 826
 827
 828
 829
 830
 831
 832
 833
 834
 835
 836
 837
 838
 839
 840
 841
 842
 843
 844
 845
 846
 847
 848
 849
 850
 851
 852
 853
 854
 855
 856
 857
 858
 859
 860
 861
 862
 863
 864
 865
 866
 867
 868
 869
 870
 871
 872
 873
 874
 875
 876
 877
 878
 879
 880
 881
 882
 883
 884
 885
 886
 887
 888
 889
 890
 891
 892
 893
 894
 895
 896
 897
 898
 899
 900
 901
 902
 903
 904
 905
 906
 907
 908
 909
 910
 911
 912
 913
 914
 915
 916
 917
 918
 919
 920
 921
 922
 923
 924
 925
 926
 927
 928
 929
 930
 931
 932
 933
 934
 935
 936
 937
 938
 939
 940
 941
 942
 943
 944
 945
 946
 947
 948
 949
 950
 951
 952
 953
 954
 955
 956
 957
 958
 959
 960
 961
 962
 963
 964
 965
 966
 967
 968
 969
 970
 971
 972
 973
 974
 975
 976
 977
 978
 979
 980
 981
 982
 983
 984
 985
 986
 987
 988
 989
 990
 991
 992
 993
 994
 995
 996
 997
 998
 999
 1000
 1001
 1002
 1003
 1004
 1005
 1006
 1007
 1008
 1009
 1010
 1011
 1012
 1013
 1014
 1015
 1016
 1017
 1018
 1019
 1020
 1021
 1022
 1023
 1024
 1025
 1026
 1027
 1028
 1029
 1030
 1031
 1032
 1033
 1034
 1035
 1036
 1037
 1038
 1039
 1040
 1041
 1042
 1043
 1044
 1045
 1046
 1047
 1048
 1049
 1050
 1051
 1052
 1053
 1054
 1055
 1056
 1057
 1058
 1059
 1060
 1061
 1062
 1063
 1064
 1065
 1066
 1067
 1068
 1069
 1070
 1071
 1072
 1073
 1074
 1075
 1076
 1077
 1078
 1079
 1080
 1081
 1082
 1083
 1084
 1085
 1086
 1087
 1088
 1089
 1090
 1091
 1092
 1093
 1094
 1095
 1096
 1097
 1098
 1099
 1100
 1101
 1102
 1103
 1104
 1105
 1106
 1107
 1108
 1109
 1110
 1111
 1112
 1113
 1114
 1115
 1116
 1117
 1118
 1119
 1120
 1121
 1122
 1123
 1124
 1125
 1126
 1127
 1128
 1129
 1130
 1131
 1132
 1133
 1134
 1135
 1136
 1137
 1138
 1139
 1140
 1141
 1142
 1143
 1144
 1145
 1146
 1147
 1148
 1149
 1150
 1151
 1152
 1153
 1154
 1155
 1156
 1157
 1158
 1159
 1160
 1161
 1162
 1163
 1164
 1165
 1166
 1167
 1168
 1169
 1170
 1171
 1172
 1173
 1174
 1175
 1176
 1177
 1178
 1179
 1180
 1181
 1182
 1183
 1184
 1185
 1186
 1187
 1188
 1189
 1190
 1191
 1192
 1193
 1194
 1195
 1196
 1197
 1198
 1199
 1200
 1201
 1202
 1203
 1204
 1205
 1206
 1207
 1208
 1209
 1210
 1211
 1212
 1213
 1214
 1215
 1216
 1217
 1218
 1219
 1220
 1221
 1222
 1223
 1224
 1225
 1226
 1227
 1228
 1229
 1230
 1231
 1232
 1233
 1234
 1235
 1236
 1237
 1238
 1239
 1240
 1241
 1242
 1243
 1244
 1245
 1246
 1247
 1248
 1249
 1250
 1251
 1252
 1253
 1254
 1255
 1256
 1257
 1258
 1259
 1260
 1261
 1262
 1263
 1264
 1265
 1266
 1267
 1268
 1269
 1270
 1271
 1272
 1273
 1274
 1275
 1276
 1277
 1278
 1279
 1280
 1281
 1282
 1283
 1284
 1285
 1286
 1287
 1288
 1289
 1290
 1291
 1292
 1293
 1294
 1295
 1296
 1297
 1298
 1299
 1300
 1301
 1302
 1303
 1304
 1305
 1306
 1307
 1308
 1309
 1310
 1311
 1312
 1313
 1314
 1315
 1316
 1317
 1318
 1319
 1320
 1321
 1322
 1323
 1324
 1325
 1326
 1327
 1328
 1329
 1330
 1331
 1332
 1333
 1334
 1335
 1336
 1337
 1338
 1339
 1340
 1341
 1342
 1343
 1344
 1345
 1346
 1347
 1348
 1349
 1350
 1351
 1352
 1353
 1354
 1355
 1356
 1357
 1358
 1359
 1360
 1361
 1362
 1363
 1364
 1365
 1366
 1367
 1368
 1369
 1370
 1371
 1372
 1373
 1374
 1375
 1376
 1377
 1378
 1379
 1380
 1381
 1382
 1383
 1384
 1385
 1386
 1387
 1388
 1389
 1390
 1391
 1392
 1393
 1394
 1395
 1396
 1397
 1398
 1399
 1400
 1401
 1402
 1403
 1404
 1405
 1406
 1407
 1408
 1409
 1410
 1411
 1412
 1413
 1414
 1415
 1416
 1417
 1418
 1419
 1420
 1421
 1422
 1423
 1424
 1425
 1426
 1427
 1428
 1429
 1430
 1431
 1432
 1433
 1434
 1435
 1436
 1437
 1438
 1439
 1440
 1441
 1442
 1443
 1444
 1445
 1446
 1447
 1448
 1449
 1450
 1451
 1452
 1453
 1454
 1455
 1456
 1457
 1458
 1459
 1460
 1461
 1462
 1463
 1464
 1465
 1466
 1467
 1468
 1469
 1470
 1471
 1472
 1473
 1474
 1475
 1476
 1477
 1478
 147

CLAIMS

1. Device for the heat insulation of at least one underwater pipe (1) intended to be laid on the sea bed at great depth, comprising an insulating coating surrounding the latter and a protective envelope (3), characterized in that said insulating coating comprises a virtually
5 incompressible liquid/solid phase change material (4) with a melting temperature T_0 higher than that T_2 of the medium surrounding the pipe in operation and less than that T_1 of the effluents circulating in said pipe, which protective envelope (3) is resistant and deformable and ensures a containment about said insulating coating.
2. Heat insulation device according to Claim 1, characterized in that said insulating
10 coating comprises an absorbent matrix (2) surrounding said pipe (1), preferably nearest its outer surface, and impregnated with said material (4).
3. Heat insulation device according to Claim 1 or 2, characterized in that the protective envelope (3), abutting on the material (4) which is solidified and rigid at least on its periphery, is adapted to support the weight of the pipe (1) and the frictions when the latter is laid from
15 the surface.
4. Heat insulation device according to any one of Claims 1 to 3, characterized in that the protective envelope (3) is deformable in order to follow the variations in volume of the insulating coating that it contains under the effect of the hydrostatic pressure and upon variations in temperature.
- 20 5. Heat insulation device according to any one of Claims 1 to 4, characterized in that the protective envelope (3) comprises at least one vent permeable to the gas that may diffuse though said underwater pipe (1) and generated by the effluents which circulate therein.
6. Device according to any one of Claims 2 to 5, characterized in that the matrix (2) is constituted by a light, cellular or fibrous material and said virtually incompressible material
25 (4) which impregnates it has a melting temperature (T_0) included between 20 and 80°C.
7. Device according to any one of Claims 1 to 6, characterized in that said material (4) has a thermal conductivity less than 0.3 Watt/meter/degree Celsius in solid phase and an enthalpy of fusion greater than 50 kilojoule/kilogram.
8. Insulation device according to any one of Claims 2 to 7, characterized in that said
30 matrix (2) occupies only a part of the volume of the annular space defined by said protective envelope (3) and said pipe (1).

9. Device according to any one of Claims 1 to 8, characterized in that it comprises distance pieces (9) regularly spaced apart along the pipe (1) on which they abut and supporting the protective envelope (3).

10. Device according to any one of Claims 1 to 9, characterized in that the protective envelope (3) is made of thermoplastics material.

11. Device according to any one of Claims 1 to 10, characterized in that said virtually incompressible material (4) is constituted, to at least 90%, of chemical compounds of the family of alkanes, preferably a paraffin comprising a hydrocarbon chain with at least 10 carbon atoms.

12. Device according to Claim 11, characterized in that said virtually incompressible material (4) comprises a paraffin comprising a hydrocarbon chain with at least 14 carbon atoms.

13. Heat insulation device according to one of Claims 1 to 12, characterized in that the outer perimeter (24) of the transverse section of said protective envelope (3) is a closed curve of which the ratio of the square of the length over the surface that it defines is at least equal to 13.

14. Device according to Claim 12, characterized in that the outer shape of the transverse section of said protective envelope (3) is an oval.

15. Device according to Claim 14, characterized in that the ratio of length of the large axis over that of the small axis of the oval is at least 2.

16. Device according to Claim 13, characterized in that the outer shape of the transverse section of said protective envelope (3) is a rectangle.

17. Device according to any one of Claims 13 to 16, characterized in that it comprises at least two pipes (1) disposed along the same plane and the transverse section of said envelope (3) is of shape elongated in the same direction as this plane.

18. Device according to any one of Claims 13 to 16, characterized in that the perimeter (24) of the transverse section of said envelope (3) comprises concave reversed curvatures (35).

19. Device according to any one of Claims 13 to 18, characterized in that it comprises a wear plate (21) disposed on a part of said outer perimeter (24) of the envelope (3).

20. Device according to Claim 19 and according to any one of Claims 14 to 17, characterized in that said wear plate (21) is disposed along one of the large sides of the

transverse section of said envelope (3).

21. Device according to any one of Claims 13 to 20, characterized in that the ratio of the square of the length of the outer perimeter (24) of the transverse section of said protective envelope (3) on the surface that said perimeter defines is at least equal to 16.

5 22. Device according to any one of Claims 13 to 21, characterized in that the protective envelope (3) comprises a lower "U"-shaped part (3₁) in which are disposed said pipes (1) and a lid (34) assembled on this envelope (3).

23. Device according to Claim 22, characterized in that said lid (34) is seam-welded.

10 24. Device according to any one of Claims 13 to 23, characterized in that the protective envelope (3) comprises a lower "U"-shaped part (3₁) in which are disposed said pipes (1) and an upper opening closed by a layer (31) of supple material cast after installation of all the internal components.

15 25. Device according to any one of Claims 13 to 24, characterized in that the envelope (3) comprises shims (27) supporting the insulating coating (2), the space included between the envelope (3) and said coating (2) being filled with a virtually incompressible fluid (4).

26. Process for the heat insulation of at least one underwater pipe (1) intended to be laid on the sea-bed at great depth, using an insulating coating surrounding said pipe and a protective envelope (3), characterized in that:

20 - said pipe (1) is surrounded, preferably directly, with an insulating coating (2) comprising a virtually incompressible, liquid-solid phase change material (4) with a given melting temperature T_0 , said incompressible material preferably being impregnated in an absorbant matrix, and the whole is contained in the protective envelope (3) which must be resistant and deformable,

25 - there are made to circulate in said pipe (1) hot effluents (6) at a temperature T_1 higher than the melting temperature T_0 of said material (4) while the ambient outside temperature T_2 is less than T_0 , the phase change material (4) then being liquefied, preferably in a part of the impregnation matrix (2₁) from the pipe (1) up to a limit of heat exchange equilibrium (19) between the pipe (1) and the envelope (3), beyond this limit (19) the material being solid,

30 - when the circulation of the effluents (6) in the pipe (1) is stopped, the temperature of these effluents (6) is maintained above a given temperature T_3 for a predetermined duration thanks to the heat transfer brought by the latent heat of solidification of said material (4) of

which the liquid part (4₁) solidifies progressively on cooling.

27. Process of heat insulation according to Claim 26, characterized in that:

- an obturator (7₂) is fixed in continuous and tight manner at the end of the outer wall of pipe (1) to be insulated;

5 - there are mounted on this part of pipe (1) elements of the absorbent matrix (2) which surround the latter completely and uniformly,

- there is fitted around these matrix elements (2) the outer protective envelope (3) which is connected at its end to the obturator (7₂),

- there is positioned at the other end of the protective envelope (3) a second obturator (7₁)

10 which is fixed on this envelope and on the pipe (1),

- the annular space included between the pipe (1) and the envelope (3) is completely filled, via one end, with said phase change material (4) liquefied and overheated above its melting temperature T₀ and until the matrix elements (2) are completely impregnated with it,

- the whole is cooled.

15 28. Process of heat insulation according to Claim 27, characterized in that:

- there are interposed between absorbent matrix elements (2), distance pieces (9) regularly spaced along the pipe (1) on which they abut,

- when all the elements of the protective element (3) have been placed in position and fixed to constitute the containment envelope, straps (17) for holding said distance pieces (9) plumb are placed in position,

20 - the annular space is then filled with said liquefied material (4) under pressure in order to deform the outer envelope (3) between said straps (17), which deformation corresponding to the increase in volume generated by the thermal expansion of the material (4) liquid at filling temperature.

Device and process for the heat insulation of at least one underwater pipe at great depth

ABSTRACT

5 The present invention relates to a device for the heat insulation of at least one
underwater pipe (1) intended to be laid on the sea bed at great depth, comprising an insulating
coating surrounding the latter and a protective envelope (3), characterized in that said
insulating coating comprises a virtually incompressible liquid/solid phase change material (4)
with a melting temperature T_0 higher than that T_2 of the medium surrounding the pipe in
10 operation and less than that T_1 of the effluents circulating in the pipe, and said material (4)
preferably being impregnated in an absorbent matrix (2) surrounding the pipe (1), preferably
nearest its outer surface, which protective envelope (3) is resistant and deformable and ensures
a containment against and about said insulating coating.

15

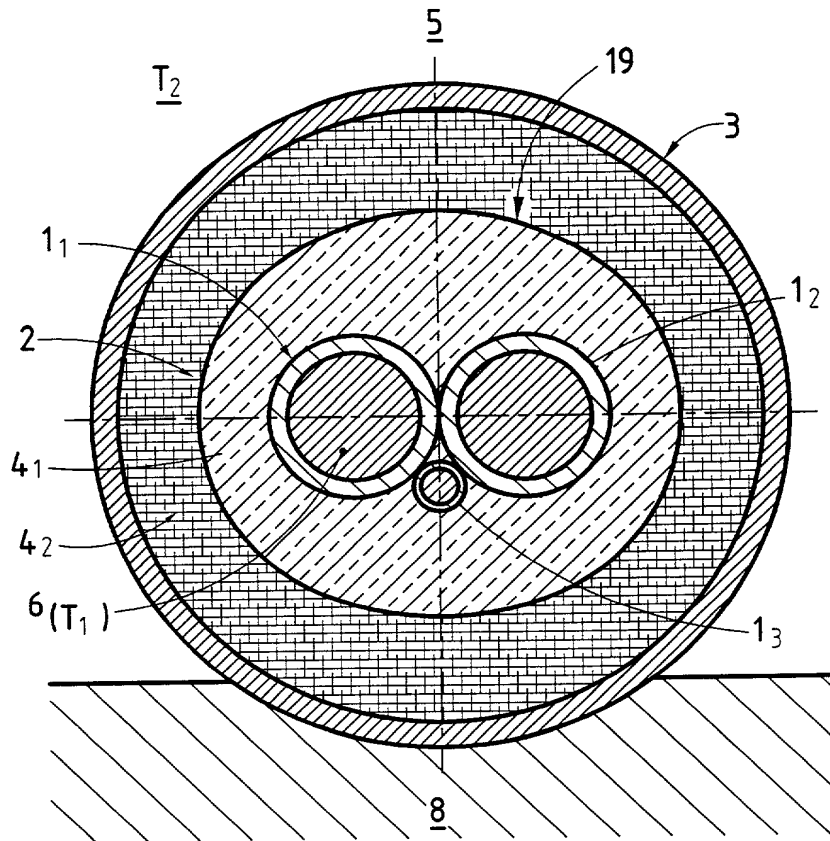


FIG.1

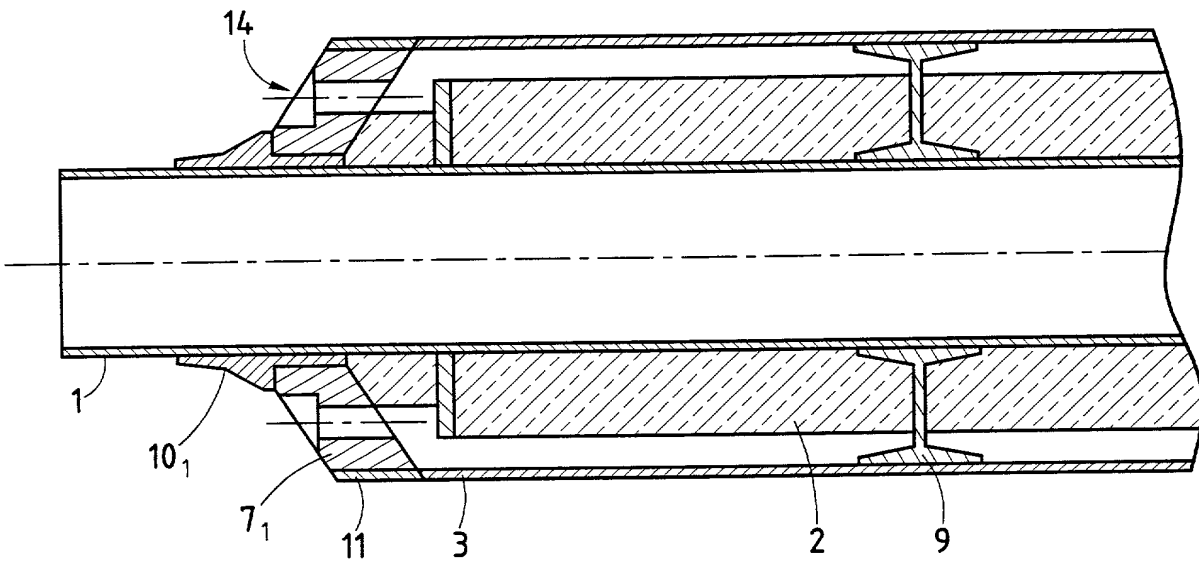


FIG.2A

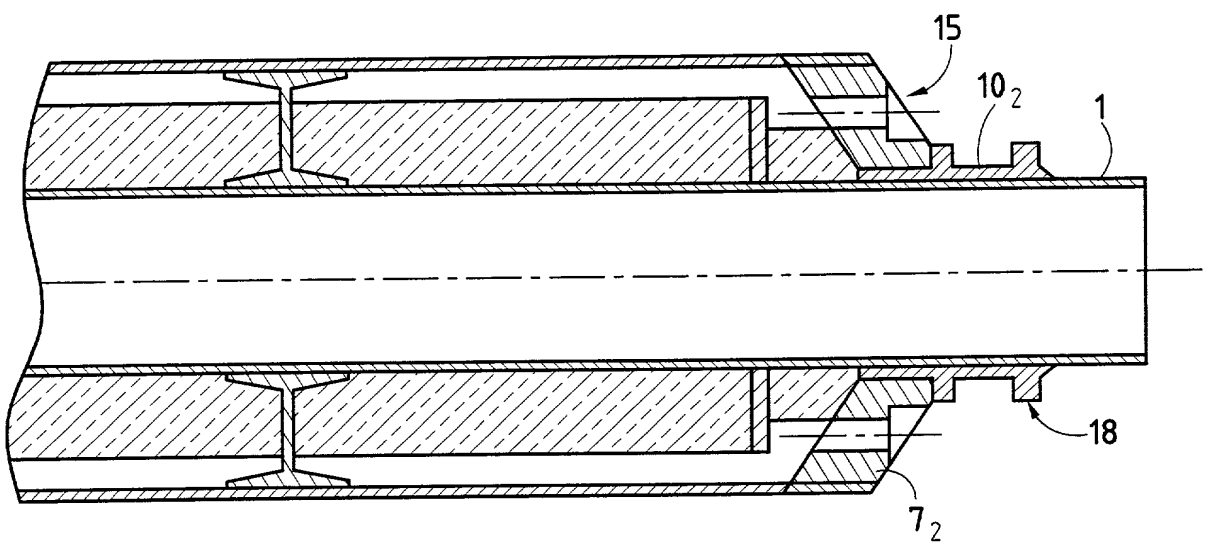


FIG.2B

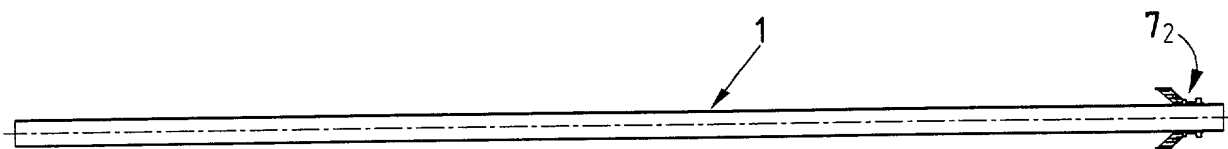


FIG. 3A

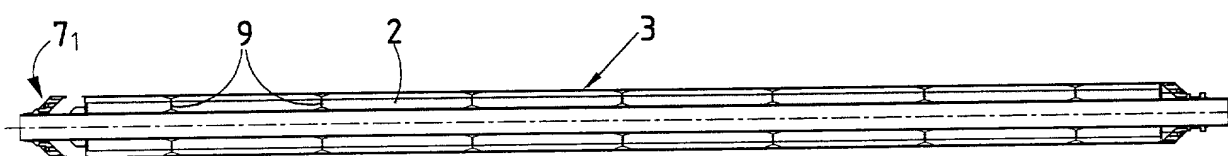


FIG. 3B

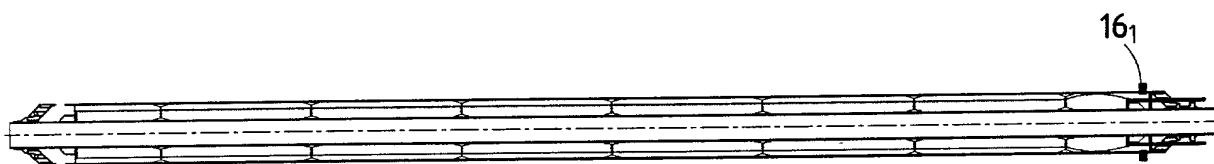


FIG. 3C

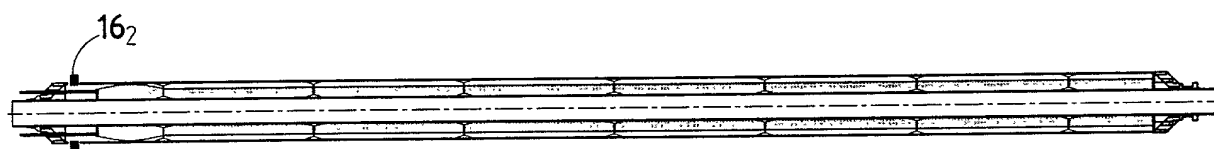


FIG. 3D

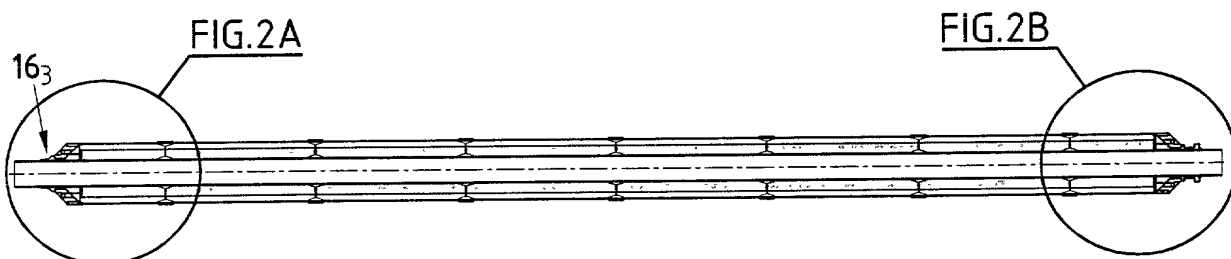


FIG. 3E

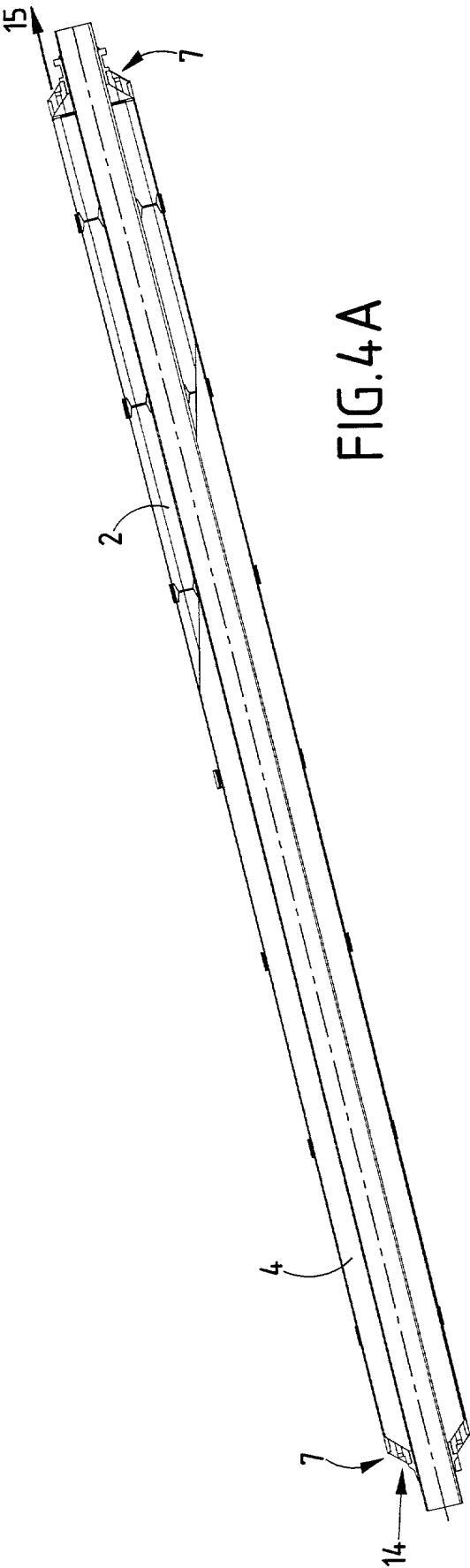


FIG. 4A

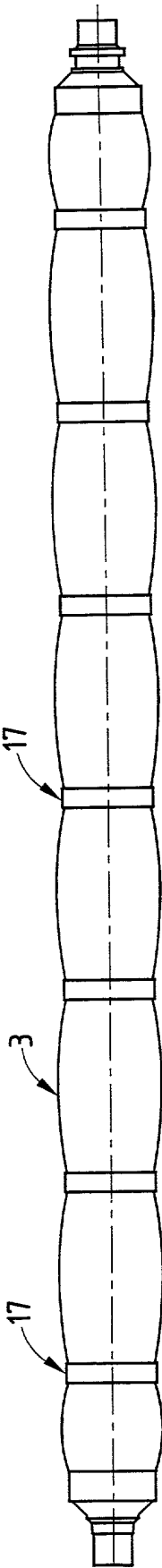


FIG. 4B

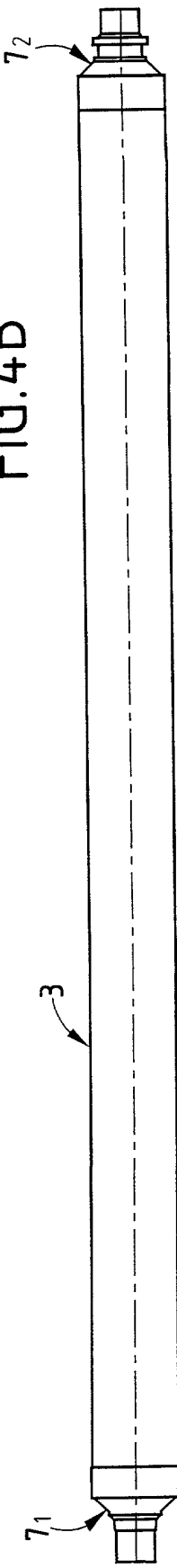
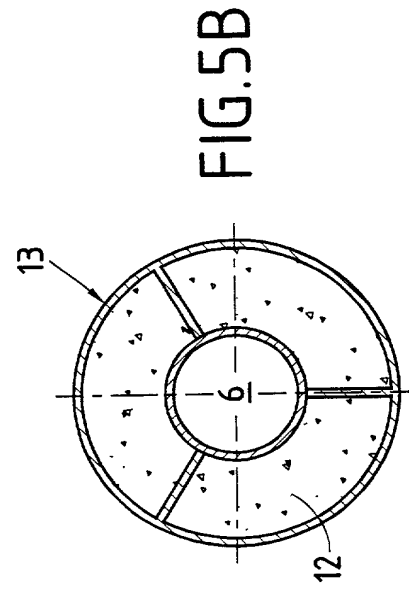
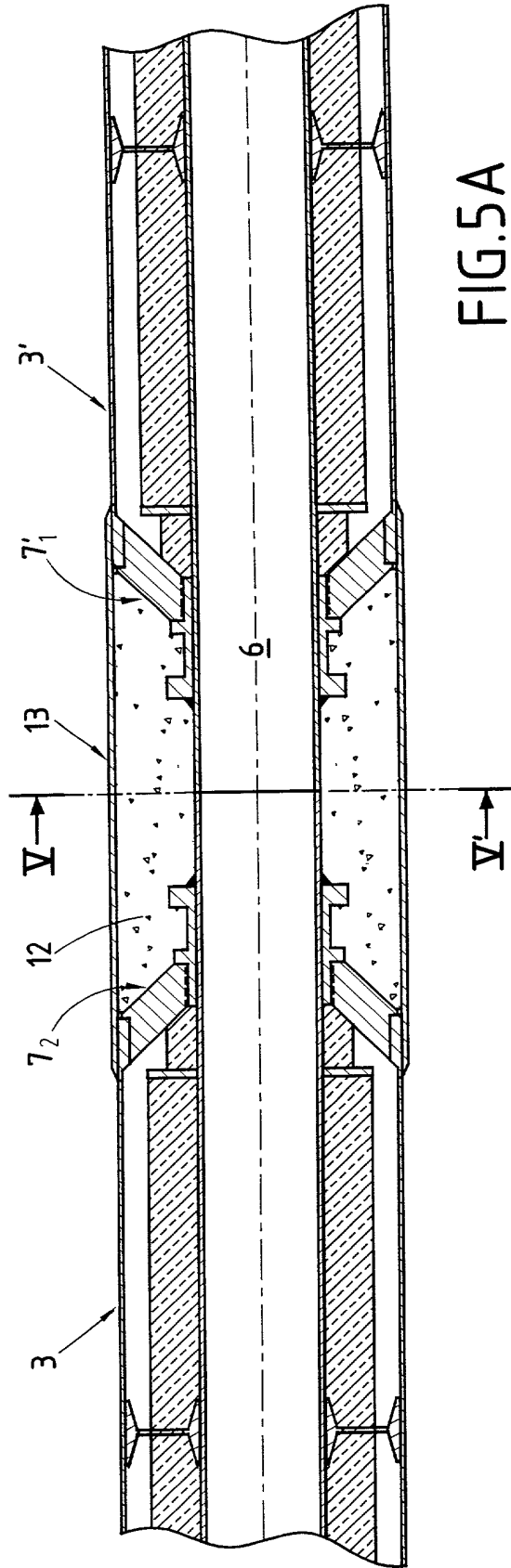


FIG. 4C



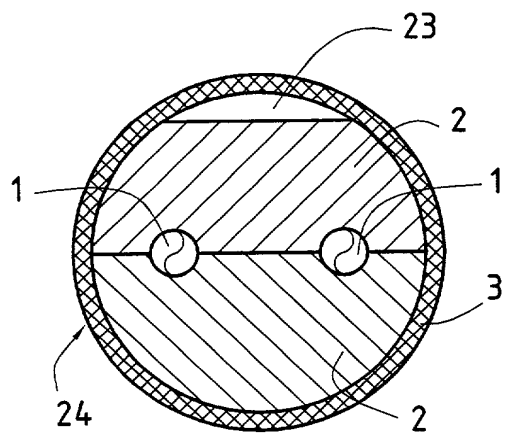


FIG. 6

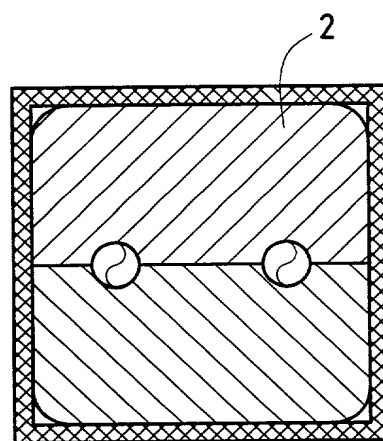


FIG. 7

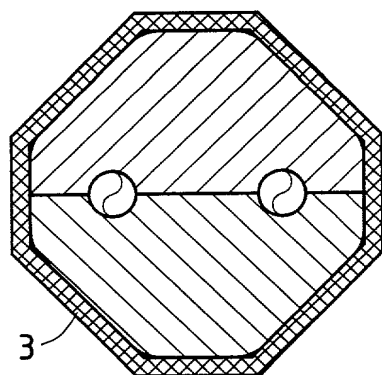


FIG. 8

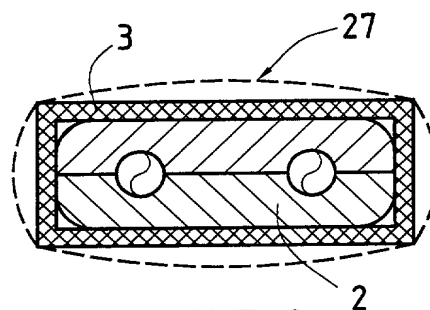


FIG. 9

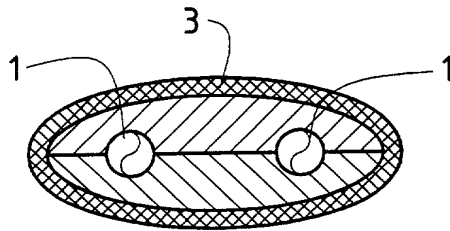


FIG. 10

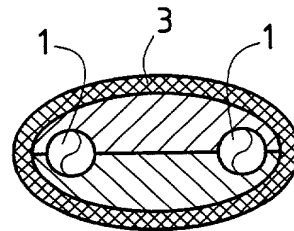


FIG. 11

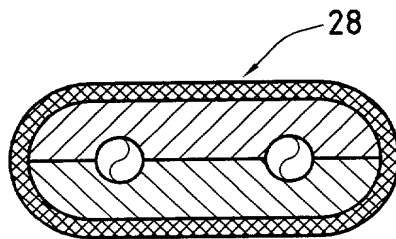


FIG. 12

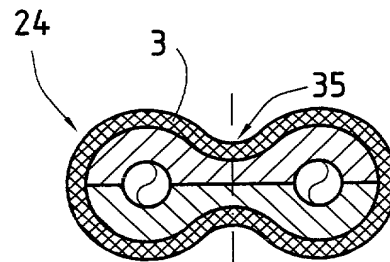


FIG. 13

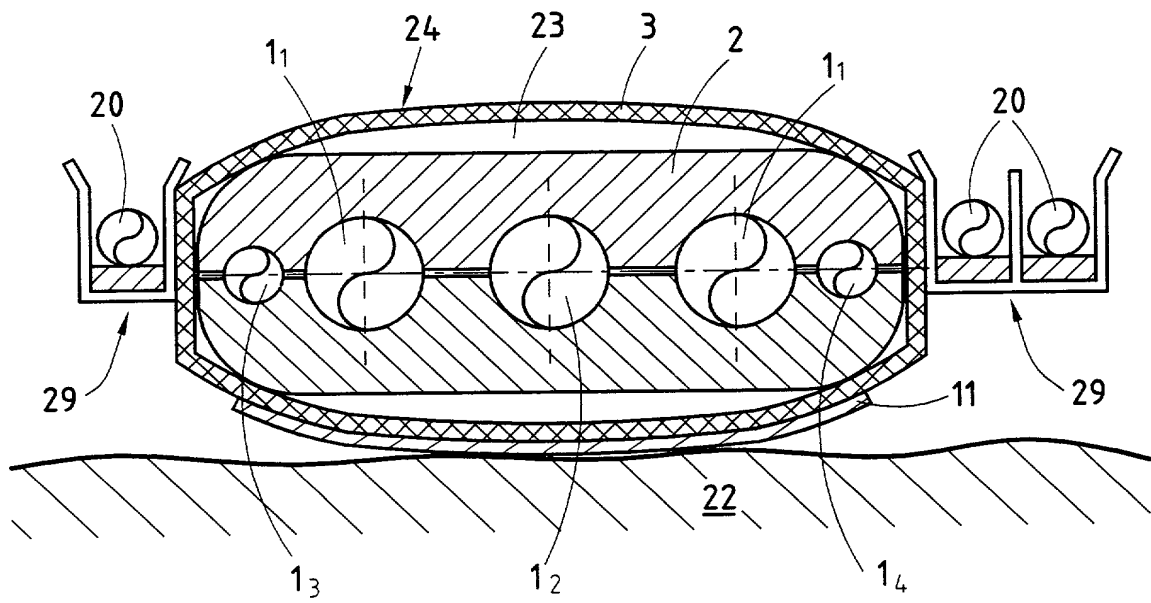


FIG.14

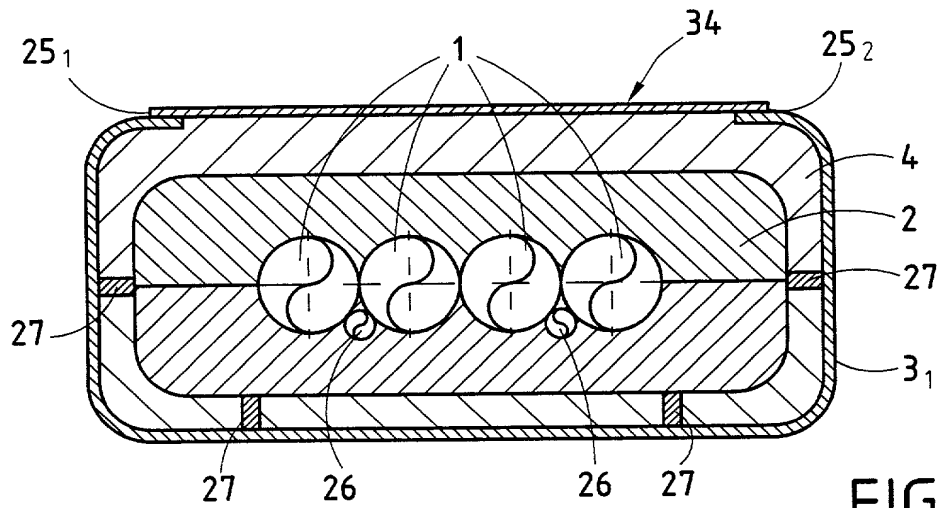


FIG. 15

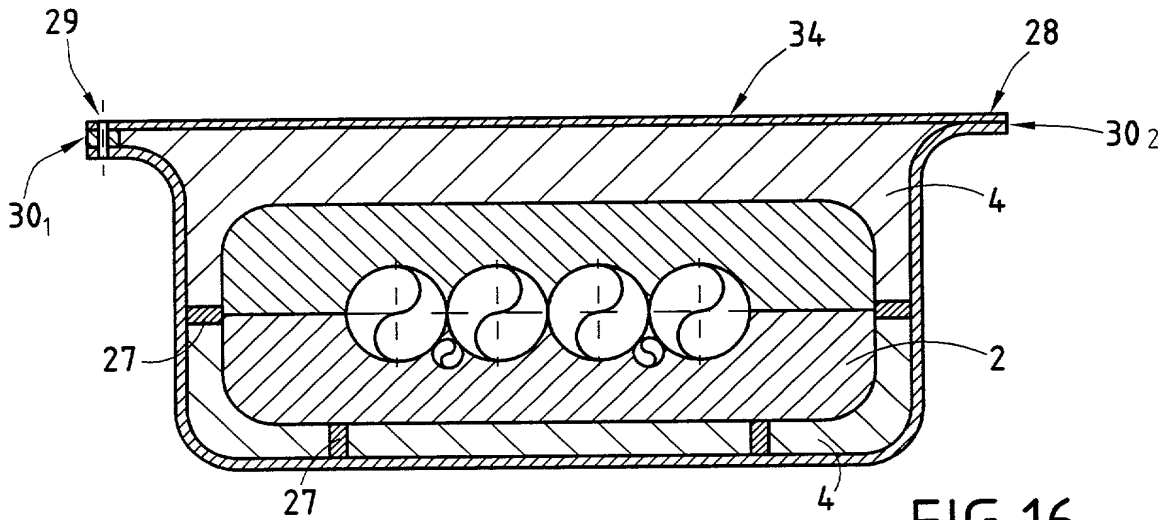


FIG. 16

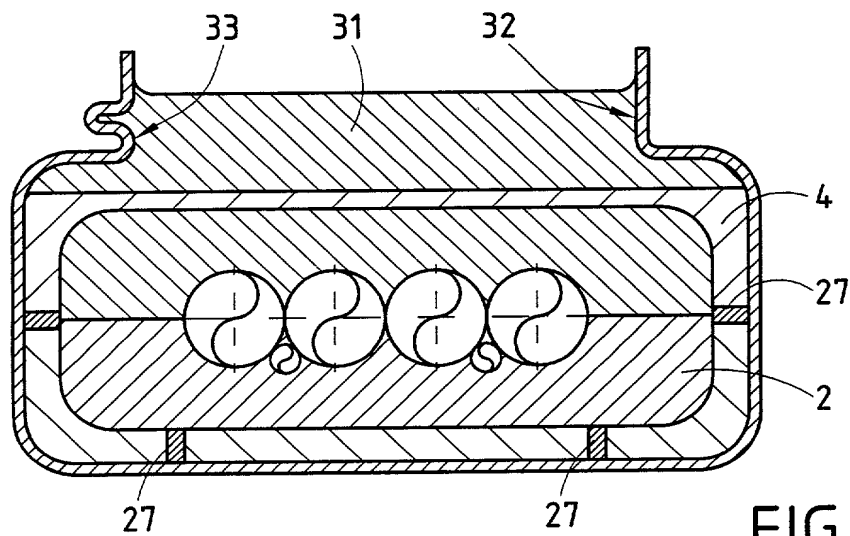


FIG. 17

STATUTORY DECLARATION

I, Barbara PELLIN, the below named Translator,
hereby declare that:

My name and post office address are as stated below:

That I am knowledgeable in the English and French
languages and am a competent translator thereof;

That I believe the English translation of the French
document attached hereto is a true and complete translation thereof.
of the PCT/FR99/03322 filed on 30 December 1999 in the name of
BOUYGUES OFFSHORE.

I hereby declare that all statements made herein of my
own knowledge are true and that all statements made on
information and belief are believed to be true; and further that these
statements were made with the knowledge that willful false
statements and the like so made are punishable by fine or
imprisonment or both, under Section 1001 of Title 18 of the United
States Code and that such willful false statements may jeopardize
the validity of the attached document.

Date: 14 August 2000

Full name of Translator: 1-00 Barbara PELLIN

Signature of Translator:



Post Office Address:

158, rue de l'Université
75340 PARIS Cédex 07

FRX